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REVIEW ARTICLE

THE IMPACT OF ADOPTING ELECTRIC VEHICLES ON VARIOUS ASPECTS OF ECONOMICS

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ABSTRACT

The electric vehicle is not a recent development. In fact, the electric vehicle has been around for over 100 years, and it has an interesting history of development that continues to the present; however the widespread adoption of electric vehicles (EVs) in place of internal combustion engine (ICE) vehicles in specific countries as a result of oil shock and recessions will have a significant impact on the global economy. The aim of this paper is estimating the possible effects of such shift in different aspects of economics as a whole.

INTRODUCTION

Switch from Oil to Electricity

The energy crisis and in particular oil shock, such as those contributed to recessions in 1973–74, 1980–81, 1991, 2000–01 and 2007–09, have made many countries concerning about alternative energy sources. In between one of the most important shifts is policies designed to transform light-duty vehicle fleet from one fuelled by petroleum to one powered largely by electricity (Robert *et al.,* 2010). As a result over the next decade, the automotive industry as a whole will experience vivid transformation. The government policies will be driven by a number of factors including stricter carbon emission standard in the country. In order to reduce the air pollution, green alternatives such as electric cars will likely find more consumer interest over the time. By year 2020, the outcome will be variety of power train technologies in the market. An entirely new class of car buyers will seek low cost, low technology cars, whereas newly wealthy customers prefer more luxurious brands in the emerging markets. In addition, the priorities of the drivers will shift away from fashionable add-ons too features designed to enhance the efficiency and safety of their vehicles in the developed markets. According to Deloitte (2009) member's firm, they estimated that by 2020, electric car and other "green" car will represent up to a third of total global sales in developed markets and up to 20% in urban areas of emerging markets. The electric vehicle is not a recent development. In fact, the electric vehicle has been around for over 100 years, and it has an interesting history of development that continues to the present; however the widespread adoption of electric vehicles (EVs) in place of internal combustion engine (ICE) vehicles in specific countries will have a significant impact on the global economy.

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History of Electric Vehicles

In the late 1800s, France and England were the first nations to develop the electric vehicles. By 1895, Americans began to devote their interest in electric vehicles. Due to this innovation, interest in motor vehicles increased significantly in the late 1890s to

1900s. During these years, electric vehicles were the highest point in America as they sold all other types of cars. Electric vehicles had many advantages compared to their competitors. They are free from vibration, smell and noise related with gasoline cars. Besides, the electric vehicle was the preferred choice of many because it did not require the manual effort to start, as with the hand crank on gasoline vehicles, and there was no wrestling with a gear shifter.

Electric vehicles enjoyed success into the 1920s with production peaking in 1912. However, by the 1920s, the production of electric vehicles were declined due to several major developments including the discovery of Texas crude oil reduced the price of gasoline so that it was affordable to the average consumer. In addition, the initiation of mass production of internal combustion engine vehicles by Henry Ford made these vehicles widely available and affordable in the $500 to $1,000 price range. By contrast, the price of the less efficiently produced electric vehicles continued to rise. In 1912, an electric roadster sold for $1,750, while a gasoline car sold for $650. By 1935, electric vehicles had all but disappeared. The years following until the 1960s were dead years for electric vehicles development and for using as personal transportation. But, in 1960s and 1970s saw a need for alternative fuelled vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil. Many attempts to produce practical electric vehicles occurred during the years from 1960 to the present. Today, various companies such as Toyota, Ford and Nissan compete with each others to produce the best electric vehicles that able to satisfy consumer needs. With large-volume production and improvements in the production process, electric vehicles are expected to reduce their price to the range of current gasoline-powered vehicles in near future.

Problem Statements

Due to the higher demand for electric vehicles, automotive companies will struggle to find the right people, with the right mix of skills at the right time and also at the right cost. But, the price of the electric vehicles will remain the most important things, and carmakers that developed greener engines will need to find ways to make these cars price compatible with more traditional internal combustion engines. Besides, with advanced in technologies, vehicles that enhance safety, efficiency and connectivity are also important to develop world customers. This transformations implied will touch on every step of the complex process involved in taking a car from a designer's imagination to a customer's driveway. The companies that thrive in the new emerging competitive field will be those that get each step right.

Microeconomics Impacts

Automotive and Electric Vehicles Industry

Automotive leaders and observers have witnessed an industry in risk for the past few years. Recession in global economy along with declining consumer confidence has transformed into gloomy new car sales in most market. Fuel taxes make for significantly more expensive gasoline in Japan and Europe which in some cases, more than double in the price of fuel in developing market. Higher oil prices have recently led to sharp declines in demand and resale values of cars, large SUVs and trucks (Thomas and Ikhlaq, 2009). Fig. 1 show declines in number of cars purchased as crude oil prices increases. However, the fall has covered many outstanding industry advancements. Without corresponding increase in price, standards of quality and productivity have been raised. Due to technological advancements and green alternative, developed countries having fierce race to develop and produce electric vehicles (EVs) that have been urged by both customer demand and government incentives. EVs are safer and more technically advanced than ever.

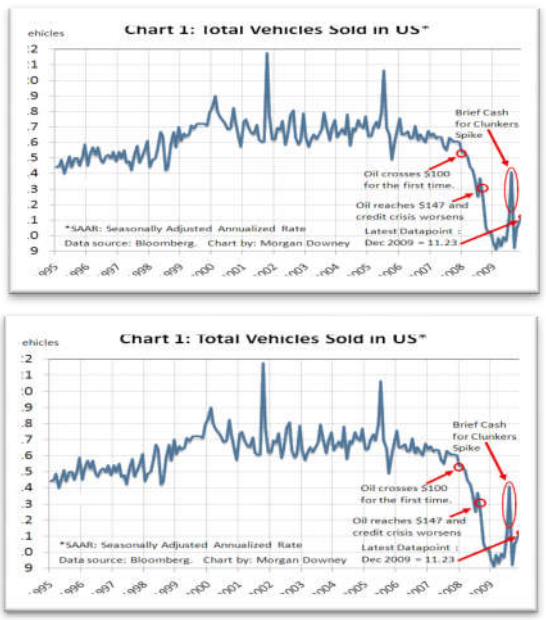
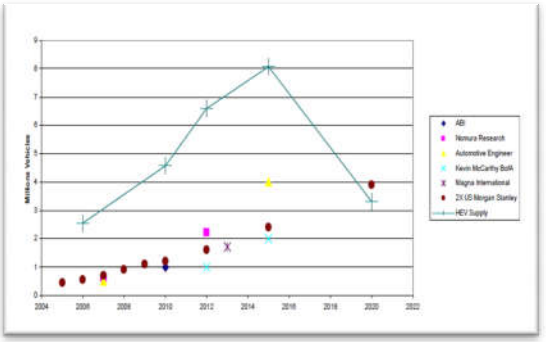


Fig. 1. The total vehicles sold in US. Chart 2 represents the forecast of EVs adoption rate in US from year 2010 to 2050

Currently, EVs represent a small fraction of total cars on the road and significantly more expensive than traditionally propelled vehicles. This is due to the costs of the lithium-ion battery. Nevertheless, growing in the environmental concerns among consumers, environmental regulation, volatility of gas and reduction will bring into a moderate increase in demand and supply for EVs by 2020. Based on the baseline forecast, electric cars account for 64% of US light-vehicles sales by 2030 and comprise 24% of the US light- vehicles fleet. The rates of adoption are driven by the low purchase price and operating costs of electric cars with separate battery ownership or battery leasing (Matt *et al.,* 2008). Fig. 2 illustrated the expected rate of EVs' adoption.



Source: Lauren Abell and Paul Oppenheimer, Naval Postgraduate School

Fig. 3. Global EV Supply

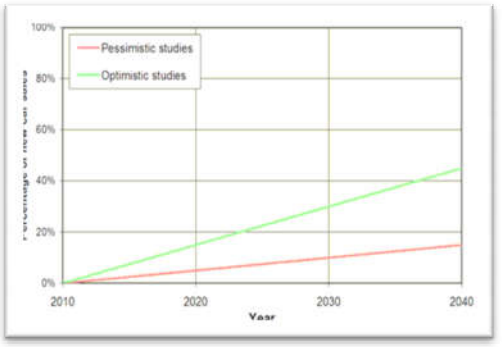


Fig.4. Light Electric Vehicle Sales Predictions

Lithium Industry

The equipment and operating costs associated with electric cars include the price of battery, the cost of the electricity to charge the battery and also the cost of deploying a charging infrastructure. The electric vehicle industry and movement basically relies on lithium (Li) based batteries. Extensive research into sources of lithium production and supply suggest there is no shortage of Li at least for the next 10 years. This is more than enough time to jump- start the electric vehicle (EV) revolution. It is important to review the EV market and attempt to forecast the future of EV demand as the economies of scale driving much of the cost- savings in lithium mining and recycling. It is possible to compare the demand with manufacturing supply with forecasts for the global and US EV market. The largest growth areas for lithium have been in the battery market, particularly secondary batteries. As clearly can be seen in Fig. 3 below, there is no supply shortage until close to 2020. All of the forecasting numbers ignored any contribution from recycling, worst case supply and demand estimates, and assumed that that all EV's use only lithium based chemistry. But, if there were to be a shortage due to increase demand, the price would also increase. By this way, this would make recycling a more profitable venture, increase exploration and likely significantly contribute to the supply chain that is not going to be a significant impact on EV production. In addition, from the global perspective, the distribution of Li not only relieves growing pressure on the oil based fuel market, but also provides a diversity of supply that spreads the wealth and allocates the technologies.

Consumers

In many situations in economics and marketing we would like to be able to forecast consumer demands for goods which have not yet appeared in actual markets. By defining goods as a bundle of underlying attributes, we can use discrete choice models to estimate consumer evaluations. Then new good demand is forecast by use of the estimated coefficients to compare consumer evaluation of the new good to existing choices. In between, some points are favouring the sale of this product e.g. home recharging and emissions, whereas some like the fact that these vehicles provide a less driving range compared to gasoline vehicle, raiseda large number of issues. In fact most previous studies indicate that driving range is a serious market barrier, while some argue that the increasing environmental image and easy recharging at home will outweigh the driving range. They argue that the utility of short range, home rechargeable electric cars lies primarily in their complementary, not competitive relation, in comparison to the vehicles with high range, quick and ubiquitous refueling (Kenneth Kurani *et al.,* 1996). In addition, the fact that the industry is thriving on adapt new designs impacted by fuel-economy and emission policies, is another positive point for the future demand of electric cars (Jerem *et al.,* 2004). In the case of the electric cars, many consulting companies have provided forecasts for

the sales of Electric Vehicle (EV) and in particular electric cars. The forecasts mainly include Battery Electric Vehicle (BEV), Plug-in Hybrid Electric Vehicle (PHEV) and Fuel Cell Electric Vehicle (FCEV) (Fig. 5). The most pessimistic ones predict that by 2020 electric cars sales will reach 3% of the annual light-duty vehicle, nevertheless the most optimistic ones on average predict 15% and even in minor cases 18% (Kenneth Kurani *et al.,* 1996; http://www.going-electric.org)

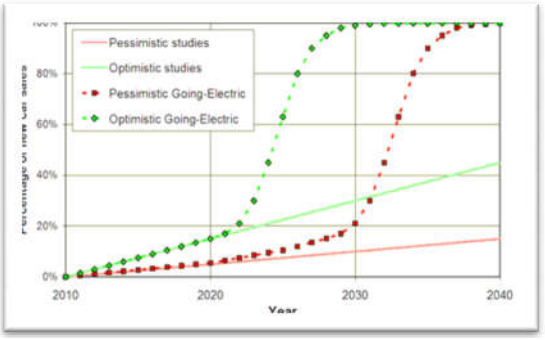
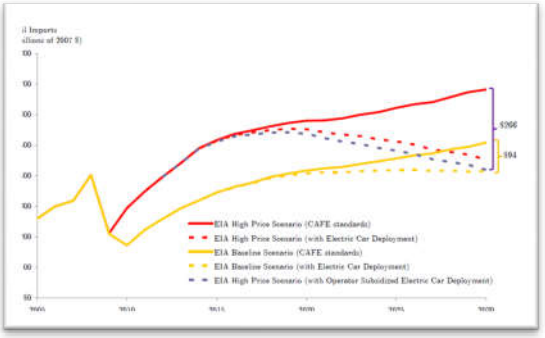


Fig. 5. Light Electric Vehicle Sales Predictions



Source: Center of Entrepreneurship & Technology, University of California, Berkeley

Fig. 6. Oil Trade Balance Under Three Scenarios for EV Adoption

According to these studies, we believe that electric car sales will increase sharply sometimes between 2020 and 2030 for the following reasons: High production volumes and technological improvements will sufficiently reduce EV purchase price to make them competitive against Internal Combustion Vehicles (ICVs). In 10 or 20 years' time, the price of oil will most probably be much higher than today, deterring consumers from using ICVs. Once EVs are accepted by consumers, public authorities are likely to restrain the use of ICVs within city limits in order to reduce urban pollution and noise and offset the cost ICV externalities (such as health effects and building renovation). This will be a strong incentive for purchasing electric cars. So if the number of EVs sold in 2020 is anyone's guess, it is very likely that electric cars will become the norm sometimes between 2030 and 2040. In order to remain competitive, car manufacturers must now start concentrating all efforts towards this technological shift. (http://www.going-electric.org)

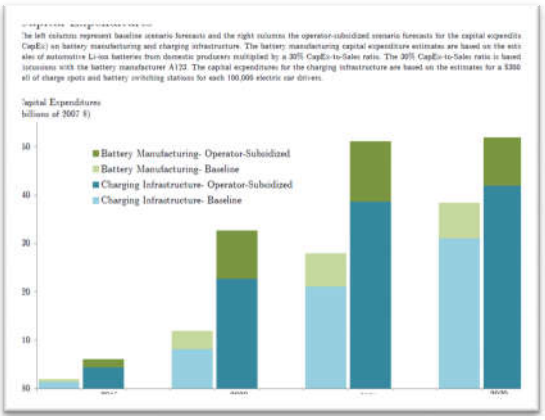
Macroeconomics Impacts

Investment

By looking at United States scenario, the decrease in the economy's consumption of petroleum will be the most direct impact of the electrification of the US light vehicles fleet. Looking at the amount of oil imported by United States, it is very hard to imagine how the US could close its trade deficit or current account deficit without decreasing its oil consumption. In 2008, over two thirds of oil was imported which United States spent almost $600 billion dollars. The deployment of electric cars will significantly reduce the transportation sector's reliance on petroleum based fuels. Therefore, this would diminish the problems associated with the oil dependency of the US economy. Thomas and Ikhlaq (2009) from University of California estimated the trade balance single out petroleum imports as the only traded good or service impacted by deployment of electric cars. They assume that the production of domestic light-vehicles will remain constant through 2030. Besides, they also assume that over the next decade, by 2019, automotive battery manufacturing industry will grow and captures the same share of domestic light-vehicle battery sales as domestically produced autos (Thomas and Ikhlaq, 2009). The lower demand for oil due to the deployment of electric cars will give downward pressure on world oil prices. Fig. 6 represents the calculation of the impact of electric cars on the US trade balance accounts for the price effect. In the higher price scenario, the impact of EV deployment is larger; however, initially the trade balance deteriorates before the EV deployment reaches adequate mass to reverse the outflow of petrodollars.

In addition, substantial financing and investment are required to deploy the infrastructure for network charge spots and battery switching stations. Researchers believed the necessary capital expenditures to deploy this network will be almost $ 328 billion over the next two decades, form that amount, $240 billion would be for charging infrastructure (Thomas and Ikhlaq, 2009). Based on the operator- subsidized scenario forecasts, there will be 151 million electric car drivers by 2030 and will require practically 80% more infrastructure

investment. The annual capital investment for United States is estimated to account between 1 to 1.5% of total US investment. Currently, United States has no large scale for domestic automotive battery manufacturing. Scientists in US research universities stated that the manufacture of the battery occurs solely in Asia. Therefore, it is important for the US to incentivize the development of a domestic battery industry in order to close US trade deficit and to ensure employment in a major growth sector as the forecasted domestic demand for automotive battery will be relatively high, $37 to $50 billion by 2030. Fig. 7 are based on the assumption that this domestic sector continues to grow over the next decade to eventually supply the same proportion of automotive Lithium batteries as domestic autos industry supplies autos.



Source: Center of Entrepreneurship & Technology, University of California, Berkeley

Fig. 7. Capital Expenditure Forecast for Baseline and Operator Subsidized Scenarios

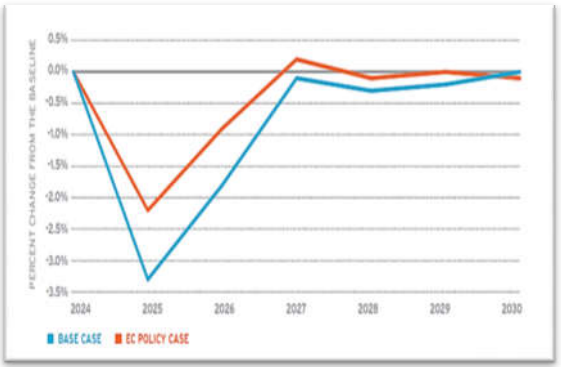


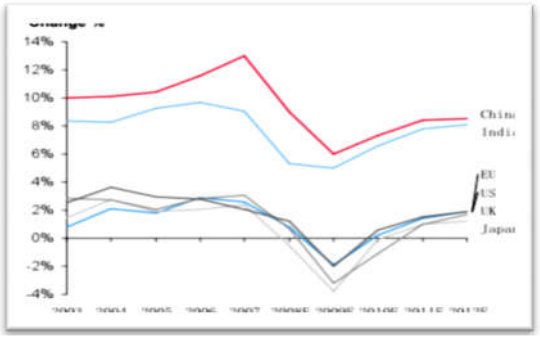
Fig. 8. Annual Impact on GDP from an Oil Shock Employment

Right key to any long-lasting transformation in the automotive industry are the primary issues of skills and workforce flexibility. In order to build more technologically advanced cars, workers need to be suitably trained to handle these new technologies. Therefore, workforce capability will have to be developed accordingly. The deployment of electric cars will effect significantly in job creation for domestic electric sector. Basically, the largest source comes from the deployment of a nationwide charging infrastructure and the projections for employment gains are made for both the charging network and manufacturing industry. Moreover, these jobs include several areas such as electric services, construction and service sector jobs which connected to operation and maintenance of public charge spots and battery switching stations (Thomas and Ikhlaq, 2009). With this adoption of electric cars, the industries that supply parts and services for the petroleum will be affected. The projected job losses to occur are among gas station attendants, auto parts suppliers and also mechanics. In general, these job losses are more than offset by the gains in domestic battery manufacturing and charging infrastructure deployment.

National Output: GDP

The gross domestic product (GDP) is one the primary indicators used to gauge the health of a country'seconomy. It represents the total dollar value of all goods and services produced over a specific time period - you can think of it as the size of the economy. As one can imagine, economic production and growth, what GDP represents, has a large impact on nearly everyone within that economy. For example, when the economy is healthy, you will typically see low unemployment and wage increases as businesses demand labour to meet the growing economy. A significant change in GDP, whether up or down, usually has a significant effect on the stock market. It's not hard to understand why: a bad economy usually means lower profits for companies, which in turn means lower stock prices. Investors really worry about negative GDP growth, which is one of the factors economists use to determine whether an economy is in a recession.

The impact of introducing electric cars on macroeconomics and especially GDP has been concerned by many countries.Nowadays many countries are concerning the positive impact of electric cars on GDP, and trying to be the first to gain profit from this innovation. As an example, a study done by the University of Maryland and Keybridge Research LLC has compared estimated GDP before and after



Source: EIU; Global Insight, OPEC, DGS Report, Booz & Company analysis

Fig. 9. Real GDP Growth: Historical & Forecast – EIU Estimates

Technology called "New Energy Vehicles", By driving this plan,consists of promoting the use of electric and hybrid electric vehicles, 60000 energy saving vehicles will be deployed by 2012. In below you can see the comparison of assessed real GDP growth forecast between automotive industry pioneer countries. It can be clearly seen that China forecast to have a significant better GDP by driving the "New Energy Vehicles" plan.

Imports& Exports

Like other aspects of electric cars' impact on global economy, this field have also been studied by various countries. At this point, it seems useful to compare the present results of impact with the forecasted ones. In the U.S. from 1998 to 2005, the net impact on imports, as

Table 1. Import by Industry

Expressed in Billions of Constant 1977 Dollars

	1998	1999	2000	2001	2002	2003	2004	2005
Crude petroleum	34.91	35.63	36.33	37.01	37.72	38.41	39.09	39.77
	-0.01	-0.02	-0.03	-0.05	-0.07	-0.10	-0.12	-0.14
Petroleum refining	7.28	7.49	7.68	7.88	8.11	8.32	8.54	8.76
	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.06	-0.07
Other nonferrous metals	8.52	8.90	9.20	9.43	9.69	9.93	10.16	10.37
	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05
Communic eq, electronic comp	37.19	38.67	40.15	41.50	42.93	44.30	45.66	47.12
	0.03	0.05	0.07	0.10	0.15	0.21	0.22	0.23
Elec indl app & distrib eq	7.63	7.99	8.32	8.59	8.94	9.27	9.59	9.95
	0.01	0.02	0.03	0.04	0.06	0.08	0.08	0.08
Elec lighting & wiring eq	5.30	5.42	5.57	5.76	5.96	6.14	6.29	6.46
	0.07	0.10	0.14	0.18	0.28	0.39	0.40	0.41
Motor vehicles	57.17	59.40	61.18	62.86	65.07	66.80	68.44	70.13
	-0.06	-0.07	-0.08	-0.08	-0.12	-0.16	-0.11	-0.06

transforming the U.S light-duty vehicle fleet from fuelled by petroleum to largely powered by electricity (Robert *et al.,* 2010). This studyoutlooks U.S economy from 2010 to 2030 and the base case (before transforming) has a real GDP growth average 2.5% over the period which is illustrated below by blue line, whereas the estimated GDP after electric car (EC) policy is displayed by red. The analysis indicates that the EC policies would mitigate roughly one-third of the GDP and employment losses caused by an oil price shock. In the first year of an oil price-led recession, the EC policies prevent the loss of 1.05% ($213 billion) of real GDP; In addition from 2025 to 2030, the EC policies prevent the loss of a cumulative $505 billion in GDP electricity (Robert *et al.,* 2010). China, another country interested on leading the transition to electric cars, also has done several studies relating this subject. One in particular estimates the impact of a plan conducted by Ministry of Science and

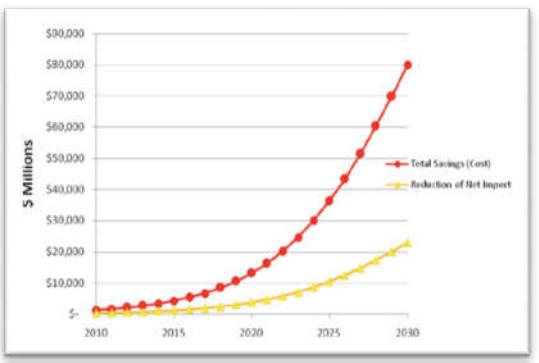


Fig.10. **Savings & Reduction in Net Imports per Year**

can be seen at the table belowwas small but positive (Douglas, 2008-2005). At the table below, the first line

Table 2:. Oil Import (mbd)

	BASE CASE	EC POLICY CASE	CHANGE
2010	11.9	11.7	(0.2)
2015	12.5	11.7	(0.9)
2020	12.4	11.0	(1.5)
2025	11.8	9.5	(2.2)
2030	12.1	8.9	(3.2)
Cumulative Reduction 2010-2030			11,908 Million Bbl

represents the figures for the base run, and the second line indicates the absolute change of the figures in the alternative run with respect to the base. As can be seen Imports of goods insome industries have increased somewhat. This increase in imports worsens the trade balance only slightly. Overall, during this period, the largest impact is a $1.1 billionincrease in imports in current dollars along with a 0.5 billion increase in exports, worsening the trade balance by about 1.5%. At this level, from a macroeconomic standpoint the long-run impacts on the U.S. economy of the introduction and penetration of the electric car are small, but they are more important for individual industries (Douglas, 2008-2005). On the other hand future forecasting for impacts of EV on imports and exports seem different, as if the electric car were to achieve, say, a 20% national penetration rate, the industrial impacts would be much larger (Douglas, 2008-2005). In fact widespread adoption of EVs leads to a significant reduction in imports, while reduction in gasoline consumption has the most significant impact on the net imports. Which means, in 2030 at an estimated 39% rate of adoption, the U.S. economy in total will retain $23 billion (2008 dollars) (Matt *et al.,* 2008).

Oil Imports and World Oil Price

Reducing transportation petroleum use would result in a significant reduction in imports of crude oil and refined petroleum products. Because crude oil and refined products constitute a significant portion of the value of all imports,the reduction in oil imports would have significant effects on trade balance. This finally leads to a lower world oil price. For example the energy demand reductions in the transportation sector caused by manipulating electrification policies (EC) would result in a total reduction of 3.2 mbd in U.S. oil imports by 2030. This is roughly equivalent to an increase in supply of 3.2 mbd for the rest of the world market. It's also forecasted that using EC policy will lead to a lower world oil price.

Based on DOE reference case published by the International Energy Outlook 2009, estimated world demand elasticity is between -0.1 and -0.35.In the EC case, the extra supply on the world oil market due to the reduction in U.S. net demand is 3.2 mbd in 2030, or about 3.3%of the world total. Therefore, assuming that the demand elasticity of the rest of theworld is -0.5, oil prices in the EC policy case would be about 6.6% lower than the base case (Robert *et al.,* 2010)

Conclusion

Green crusaders have long offered a scenario where electric vehicles would diminish the burning of fossil fuels. Other analysts have suggested that the impact on oil consumption will be negligible because of limited driving ranges for all-electric vehicles. Meanwhile in different countries, government and companies are increasing their investments on electric vehicles. As instance, China is increasing from 13 to 20 cities the participants in a pilot program to subsidize the purchase of clean energy public transport vehicles. In conclusion, electric vehicles may impact economics either directly e.g. GDP; or indirectly e.g. demand for oil, depending on many factors discussed in this article. This impact does not appear to be something that will have significant affect in the next 4-5 years. By 2020, maybe. The future of electric vehicles will depend on policy actions by governments, innovation and development yet to occur and how fast the price of oil rises.

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